Augmented Reality for an Ethnobotany Workbook

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1. Introduction

In earlier work, Seth et al. developed the "Ethnobotany Study Book" [22], based on a "Prairie Garden Legacy Brochure" form the Pioneers Park Nature Center, in Lincoln, Nebraska. The workbook is designed to teach high school students about the native plants of Nebraska. Funded by a Science Education Partnership Award (SEPA), the workbook was extended to include the names of the plants in local Indian languages (Dakota, Lakota, Ho Chunk, and Omaha), as well as information about uses of the plants by Indians and early European settlers. The workbook features text descriptions and black-and-white drawings of fifteen species of plants native to Nebraska, as well as a map, glossary, references, and space for student notes. Figure 1 shows an example of a page from the workbook.

In collaboration with the University of Nebraska Medical Center (UNMC), we extended the paper work book with inexpensive Augmented Reality, to create a "magic book" effect [4, 10], through which the plants can be seen to "pop up" in three dimensions off the page. Augmented Reality (AR) is a technology that allows content creators to merge two media for the purpose of an enhanced reading experience: traditional printed material (such as books) and 3D computer graphics [3, 20, 23]. The physical book's location and orientation are tracked by a low cost camera such as a web cam or the camera of a cell phone, so the graphics move as the physical object is manipulated.

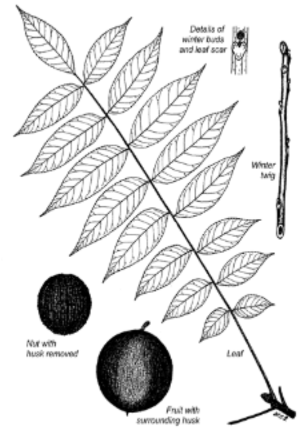
For the Ethnobotany workbook, we created 3D renditions of the 15 plant species in the book, along with a software application that recognized 15 unique markers, which displays one of the plants floating atop each marker. These markers can be printed out (e.g., on sticky paper), and affixed to the appropriate pages of the workbook.

The workbook will look almost the same with the addition of the markers, and can be used just as before. But with our AR application and an inexpensive web camera, the plants will pop off the page in 3D on the computer screen. The software package will be available for inexpensive computers that can be used in a classroom, nature center, or at home.

Black Walnut (eastern black walnut, American walnut)
Juglans nigra
Walnut family: Juglandaceae

Dakota: Hma **Ho Chunk:** Chak **Omaha:** Táge

Flowering Period
Mid April to mid June



Description
Medium sized tree. Height: 70-150 feet tall. Usually matures in about 150 years. The branches are widely spread and form a massive crown. The bark is thick and brown to grayish-black in color with deep furrows and narrow forking ridges forming a diamond pattern. The large fruit ripens between September and October. It's seed is sweet and edible.

Habitat
Found in f elds and rich woodlands. Thrives in deeper, well-drained, neutral soils. Must have direct sunlight to grow optimally.

Propagation
By seed is recommended. Should be planted in the fall in moist, well-drained deep soil that is rich in organic matter.

Plains Indian/Settler Uses
The bark was used by many native groups in tea as a laxative, chewed for toothaches, and ground to make brown and black dyes. Black walnut was also used to treat athlete's foot, hemorrhoids, and as an insecticide. A paste was also created from the leaves and husk of the fruit for treatment of ringworm.

Additional Information
The bark should be used cautiously in medicine, because it is poisonous. Black walnut creates a toxin knows as "juglone," which inhibits the growth of other plants around it, thereby reducing competition.

Figure 1 Example text from the Ethnobotany workbook (1:2 scale).

2. Description of the Product

This project produced a self-contained computer application, including all the software, printable markers, and three-dimensional graphics that can pop up from the book on the computer screen. The software will be available for PC and Mac, and, in the future, for some smart phones and tablets.

The system is designed to use a camera that should point at a table or desk (rather than at your face). See Figure 2 for the general idea. The application will work with built in cameras (typically facing the user), but the interaction is awkward in that configuration.

The software is designed to recognize and track specific black-and-white squares. There are fifteen markers, one for each species of plant in the workbook. Each marker is labeled to indicate which plant it is keyed to.[1] Figure 3 shows one of the markers.

To use the markers, print the PDF file, cut out the squares, and affix them to the appropriate pages of the workbook. The markers may placed anywhere on the page, but

[1] The computer recognizes the black square with its characteristic pattern of bars. The words are only used to help people know which marker goes with which plant.

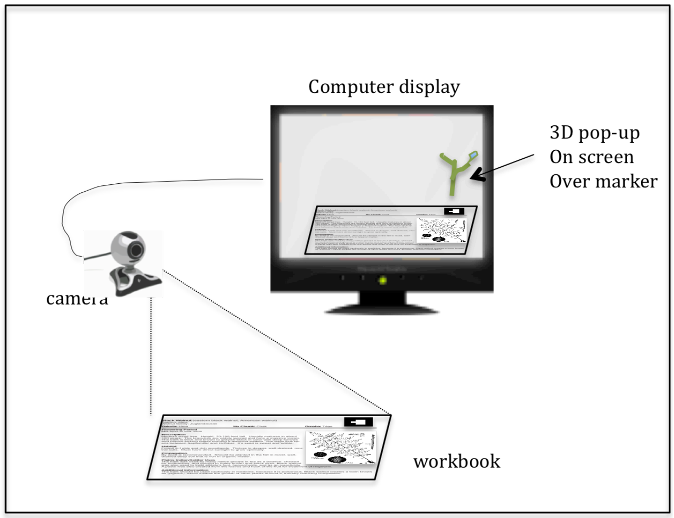


Figure 2. Sketch of the set up the camera so it points to the desk or table in front of the computer screen.

Figure 3. Example marker (actual size).

they work best if they are on a white area. A marker will work at any orientation, so long as it is visible to the camera.

Note that the markers can be used anywhere—not limited to the work book. You can attach them to any object, or hold them in your hand. Also, the graphics can be pasted into a document which is printed out.

When the markers are ready, start the application. If dialogs appear, click 'OK'. The initial window should show a view of the table and any objects in the area. When the screen shows the live video, the application is ready to explore the Augmented Reality workbook.

Open the workbook to a page describing a plant. Hold the book under the camera, generally about a foot (25-30 cm) from the lens. The exact position depends on the camera and your set up.

Figure 4. Example view of an augmented work book page (actual size depends on dimensions of the computer screen)

When the workbook is in view and shows up on the screen, move the book around until the marker is in view. When the marker comes into view, the 3D content should pop up. Figure 4 shows an example of what the application shows.

Flipping to another page, a different plant will pop up. As the workbook is moved, the 3D plant remains over the marker. Moving the book around lets you see all sides of the 3D object.

3. The Development Process

NCSA collaborated with UMNC to create appropriate 3D renderings for the selected 15 target species. This activity required interaction of scientists, educators, and artists, in order to develop legible, accurate, yet technically correct 3D renditions of the plant species. The computer graphics modules are scientifically accurate, but for this application, the models were not intended to be highly detailed or photo realistic. The goal was the artistic development of 3D models which represent salient views of the plants, at a resolution and scale that will be legible on relatively small screens.

The graphics were integrated into a simple AR application. The application was built using the ARToolkit, version 4.5, from ARToolworks, Inc. [1]. The application was configured to include the fifteen 3D models, the 15 markers, and to associate the marker-plant pairs.

The application included initial documentation and package for distribution on PC and Mac.

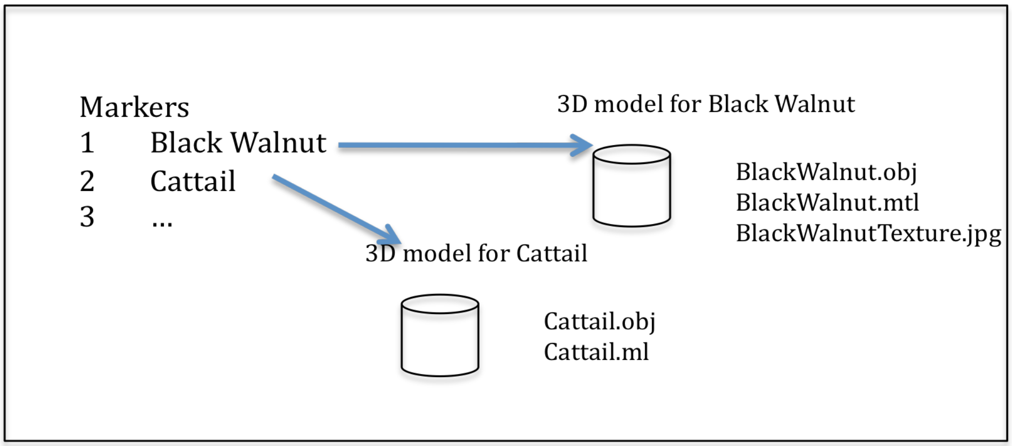


Figure 4. The AR application manages the association between markers and 3D models stored as files

3.1. Software Architecture

The application is built using the ARTookKit libraries licensed from ARToolworks [1]. The graphics were stored in .obj files ([25]), which are read using the OpenSceneGraph library ([16]) called by the ARToolKit. The ARToolkit use OpenGL (different implementations for each platform) to present the video, and appropriate device drivers and libraries to acquire video from the camera.

The application uses the ARToolKit library to manage the collection of markers and the mapping of the markers to specific models. The mapping is defined in configuration files. Figure 5 shows an example of the associations required for the AR application. In this example, marker #1 is to be associated with the image of the "Black Walnut" tree, which is stored in three files, (BlackWalnut.obj (the geometry), BlackWalnut.mtl (the colors), and BlackWalnutTexture.jpg (the surface details)). Similar associations are defined for each of the markers and graphical objects.

Principle of operation

The Augmented Reality application has a simple operational principle: capture the video input from the camera, add 3D graphics to the scene, and display the augmented frames as a video stream. The graphics are added through the following process:

1) analyze the frame to locate any markers in view,
2) analyze the position of the marker(s) (distortion of the marker from square indicates the angle of the surface relative to the camera),
3) project the graphic model associated with the marker(s) onto the scene and render into the frame, and
4) push the frame to the output stream.

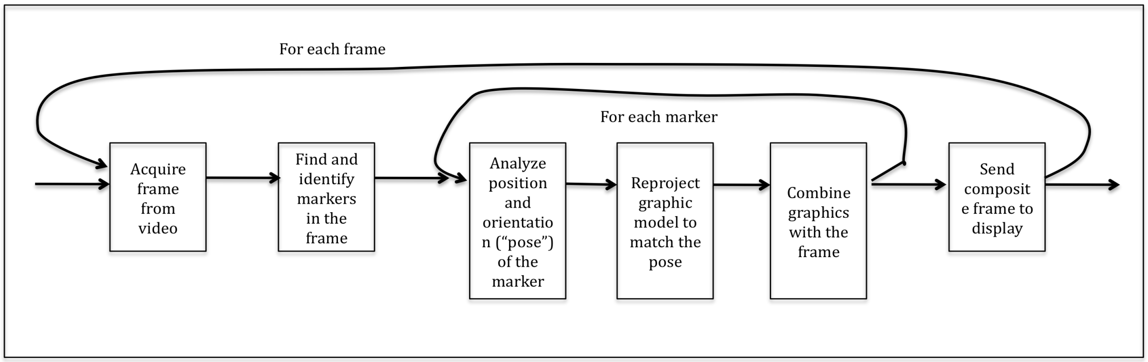


Figure 5 The main loop of a simple AR application.

Figure 6 shows the operations in the main loop. This loop is executed for each video frame, and must maintain sufficient speed to produce frames at a rate of 25 frames per second or more, with minimal delay.

3.2. Graphics Development

The 3D graphics were created by a graphic artist (Rocha) using Maya [2]. The techniques used are standard practice, widely used in the creation of movies and games.

Each plant was modeled as a mesh of points connected into polygons. Color, details (e.g., veins of the leaves), and other properties were added to the surface. The resulting dataset was writing to a .obj file ([25]), along with associated material and texture files. The .obj format is widely used for the exchange of 3D graphics for video games and other applications.

4. Discussion

This application is a simple and classic example of an Augmented Reality "magic book", as described in [4, 7-11, 13, 19, 27]. Often, it may be difficult to fully appreciate this application from a written description: it must be experienced first hand (literally, in your hands!) to understand how "magical" this technology can be.

This project demonstrated that this technology can now be available for low cost, commonly available desktop systems equipped with inexpensive web cameras. Thus, it is now within reach of classrooms and even home computers.

Augmented Reality technology will soon be available on smart phones and tablets such as iPhones, iPads, and Android devices. Our experience indicates that these platforms are not quite powerful enough to support the AR application described here, but they soon will be. We expect AR apps to become common on mobile devices in the next few years.

This project was built using the commercially available library licensed from ARtoolworks, Inc. [1]. In earlier work, we investigated the free, open source software available (e.g., [12, 15, 17, 18, 24]). To date, the available free software does not perform well, does not work on all platforms, and does not read many graphics formats (see also our earlier reports [6, 21]). For these reasons, we resorted to the high quality, supported commercial software.

Developing the 3D graphics was at least as important as the software application itself. In AR applications, as in video games and movies, developing outstanding graphical content is both labor-intensive and crucial to the success of the product.

The software application developed for this project can be reused for other "magic books". To use with another book all that need be done is to create new 3D graphics and revise a few configuration files. But, as noted, creating appropriate and beautiful graphics for a new topic should not be considered a trivial task.

The same AR application can be used for other "magic" applications, such as museum installations [5, 10, 14, 26]. In a museum, for instance, the AR can enable interactive visualization of objects otherwise inaccessible behind glass.

Augmented Reality emerged in research labs more than a decade ago. This project has demonstrated that it is now ready and accessible for broad use.

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